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# Local Entropy and Standard Deviation forFacial Expressions Recognition in Thermal Imaging

**Yomna M. Elbarawy[1], Rania Salah El-Sayed[2], Neveen I. Ghali[3]**
[1,2]Al-Azhar University, Faculty of Sience, Cairo, Egypt
[3] Future University in Egypt, Faculty of Computers & Information Technology, Cairo, Egypt

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**ABSTRACT**

Emotional reactions are the best way to express human attitude and thermal imaging mainly used to utilize detection of temperature variations as in detecting spatial and temporal variation in the water status of grapevine. By merging the two facts this paper presents the Discrete Cosine Transform (DCT) with Local Entropy (LE) and Local Standard Deviation (LSD) features as an efficient filters for investigating human emotional state in thermal images. Two well known classifiers, K-Nearest Neighbor (KNN) and Support Vector Machine (SVM) were combined with the earlier features and applied over a database with variant illumination, as well as occlusion by glasses and poses to generate a recognition model of facial expressions in thermal images. KNN based on DCT and LE gives the best accuracy compared with other classifier and features results.



***Corresponding Author:***

Yomna M. Elbarawy,
Al-Azhar University,
Faculty of Sience, Cairo, Egypt
Email: y.elbarawy@azhar.edu.eg

## 1. INTRODUCTION

Although recognition using thermal images has overcome many challenges of the recognition if compared to visible images as illumination [1], [2]; still thermal images faces its own challenges as temperature [3], aging problem and illumination [4], as well as occlusion by glasses and poses which will be tackled in this research.

In 2005 L. Trujillo et al. used Local and Global feature extraction methods using interest point detected by Harris detector clustered by K-means with Support Vector Machine SVM as classifier over IRIS database achieving 76.6% accuracy [5]. Shangfei Wang et al. in 2012 introduced temperature difference features and voting strategy with K-Nearest Neighbor KNN as classifier applied over USTC-NVIE database making 61.62% recognition rate [6].

Deep Boltzmann machine DBM model was used by Shangfei Wang in 2014 for emotional recognition with accuracy rate 62.9% over the USTC-NVIE database [7]. 98.2% recognition rate was achieved by M.H. Abd Latif et al. [8] through the use of Gray Level Cooccurrence Matrix GLCM as a feature extractor and KNN as a classifier over a new database gathered by the paper team at the International Islamic University in Malaysia.

This paper introduces the use of Local Entropy and DCT filters as a feature extractors and KNN as classifier to approach a solution for expression recognition in thermal images. The used dataset is Imaging, Robotics and intelligent systems (IRIS) database. Pose variation challenge appears with this database since every object (person) has 11 poses for each expression. Although this variation poses problem the proposed model with the LE still gives accuracy higher than the same model with other different features like Principle Component Analysis PCA and Local Standard Deviation as explained ahead.

The remainder of this paper is ordered as follows. Section 2 gives a brief introduction to feature extraction methods, local standard deviation, local entropy and principle component analysis and discrete cosine transform technique. Classification methods Support vector machine and K-nearest neighbor are also discussed in Section II. Detailed proposed model is given in section 3. Section 4 shows the experimental results and analysis. Conclusions are discussed in Section 5.

## 2. PRELIMINARIES

This section introduces a literature survey on different preliminaries given in this work.

### 2.1. Feature Extraction Methods

#### 2.1.1. Local Standard Deviation

Statistically SD is the square root of variance which a way to determine unevenness of objects [9]. Here LSD is applied on thermal images to indicate the degree of variability of the intensity values of pixels in an image. LSD acts as a feature extraction method as shown in figure 1. SD calculation illustrated in algorithm 1 and (1). Where $n$ is number of pixels, $x$ represents one pixel in an image and $\bar{x}$ is the mean of the image.

| **Algorithm 1 :** Standard Deviation Algorithm |
|---|
| 1-Find the mean of the image. |
| 2- For each pixel, find the square of its distance to the mean. |
| 3- Sum the values from Step 2. |
| 4- Divide step 3 by the number of pixels. |
| 5- Take the square root for step 4 |

$$SD = \sqrt{\frac{\sum_{i=1}^{n}|x-\bar{x}|^2}{n}} \quad (1)$$

#### 2.1.2. Local Entropy

Local Standard Deviation filters image by replacing every value by the information entropy of the values in its range r neighborhood. The entropy represents the information associated with a single pixel of the image by calculating the probability distribution function of the image [10]. Firstly proposed by Claude Shannon in 1948 and used widely ever since. Local SD represented by (2) and (3). Where $E(I)$ is the Shannon entropy of a random pixel $I$, $p_j$ defined in (3) with $i_j$ indicating the jth possible value of $I$ out of $n$ pixels and $p_j$denoting the possibility of $I = i_j$ .

$$\mathrm{E(I)} = -\sum_{\mathrm{j=1}}^{\mathrm{n}} \mathrm{p_j} \log_2 \mathrm{p_j} \quad (2)$$

$$p_j = P_r(I, i_j) \quad (3)$$

#### 2.1.3. Principle Component Analysis

Principle Component Analysis (PCA) technique used widely in recognition field as in [11] and [12]. Its basic steps illustrated in algorithm 2.

| **Algorithm 2 :** PCA Algorithm |
|---|
| 1- Input data normalization. |
| 2- Covariance matrix calculation. |
| 3- Finding the eigenvectors of the covariance matrix. |
| 4- Data interpretation into terms of components and compose a feature vector. |

#### 2.1.4. Discrete Cosine Transform

First introduced in 1974 and evolved over time [13]. DCT used in various image compression and recognition schemes [14], [15]. DCT matrix U is invertible and orthogonal so that $U^T = U^{-1}$. In (4) $C(u, v)$ computes the $u, v^{th}$ entry of the DCT of the image. $f(x, y)$ is the $x, y^{th}$ element of the image represented by matrix f. N is the size of the DCT block.
$u, v$=0,1,2,…,N - 1 and $\alpha(u), \alpha(v)$ calculated as in (5).

$$C(u,v) = \propto(u) \propto(v) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} f(x,y) . \cos\left[\frac{\pi u(2x+1)}{2N}\right] . \cos\left[\frac{\pi v(2y+1)}{2N}\right] \quad (4)$$

$$\propto(u) = \sqrt{\frac{1}{N}} \rightarrow u = 0 \text{ and } \propto(u) = \sqrt{\frac{2}{N}} \rightarrow u \neq 0 \quad (5)$$

## 2.2. Classifiers

### 2.2.1. K-Nearest Neighbor

KNN is a non parametric lazy learning algorithm [16]. Most of the training data is needed during the testing phase and usually makes decision based on the entire training data set in contrast to other techniques like SVM where it can discard all non support vectors. In the general model KNN used as a classifier of testing images in classification frame Figure 1. The major steps of KNN illustrated in algorithm 3.

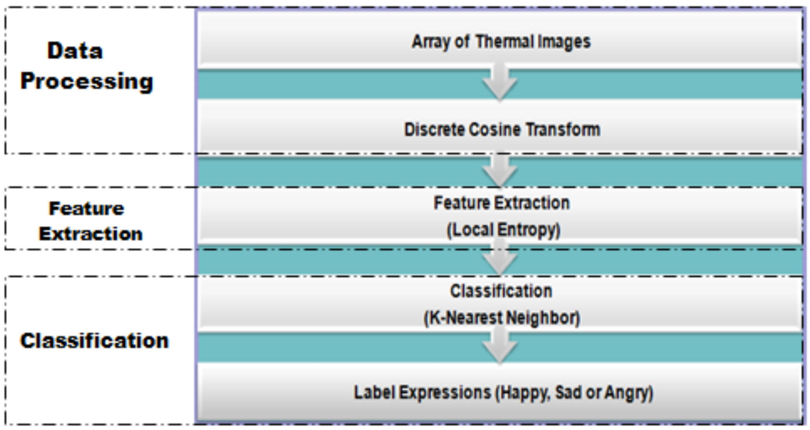


Figure 1. Proposed framework for facial expression recognition

**Algorithm 3 :** KNN Classification Algorithm

1- Input dataset as:
- Training (labeled data).
- Test (unlabeled data).

2- Calculate distances of all training vectors to test vector according to Euclidean metric.
3- Pick k closest vectors and predict class by majority vote.
4- Calculate average/majority by inverse distance.

### 2.2.2. Support Vector Machine

Support Vector Machine (SVM) is a supervised machine learning algorithm [17] earlier used for two-class grouping problems. Introduced firstly by Vapnik in 1992 by proposing a non-linear classifier and using kernel trick in 1995 [18].

SVM used a kernel function to classify a set of data into a two class groups. SVM can classify data into multiple classes [19] by Training it for each possible pair of classes and classify an unknown point p by applying each of the classifiers and count how many times point p was assigned to a certain class label. Finally, the unknown point assigned to the class label with highest count.

## 3. PROPOSED METHOD

The proposed framework is shown in Figure 1 which involves three main frames: data processing, feature extraction and classification. The first frame, data processing which covers image acquisition, pre processing. Second frame (feature extraction) applied here using two techniques: Local Entropy and image transformation using Discrete Cosine Transform. Finally the last frame (data classification) used K-nearest neighbor as classifier.

*Image acquisition*: The used data was selected from IRIS database, since it has a different poses for each subject. Only poses less than 45$^{\circ}$ rotation were used here. Further information about the database is illustrated later.

*Image transformation* was done by using discrete cosine transform filter as in Figure 2. Then, a texture based feature extraction method (Local Entropy) applied over the processed images.

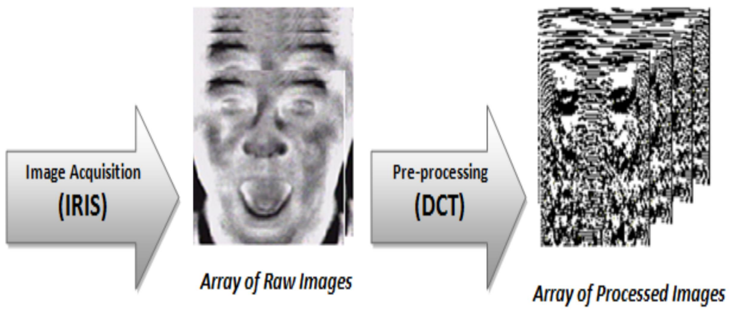


Figure 2. Image acquisition and pre-processing

Two *classification* methods were applied in order to find a suitable class label for each test image. First, multiclassification using SVM by training two-class SVM for each pair classes (Surprise and Happy, Happy and Angry and Angry and Surprise) then by counting how many times each image assigned to a certain label class. Classified image belongs to the label class (Surprise, Happy or Angry) with the highest count. Second, KNN applied by calculating distance between each test image and training images using Euclidean distance and predict image class label by the majority voting of the closest training images.

## 4. EXPERIMENTAL RESULTS

### 4.1. Data Set

IRIS dataset in the OCTBVS database which contain images in bitmap RGB format. The database contains approximately 3500 thermal and visible images with size 320 x 240, collected by the long wave IR Camera (Thermal-Raythoen Palm IR-Pro) at the University of Tennessee having uneven illuminations and different poses.

This work used 60 (30 for training and 30 for testing) images since the database has variant illumination, as well as occlusion by glasses and poses. Only poses less than 45$^{\circ}$ rotation were selected. Each subject has three different expressions Surprise, Happy and Angry. Table 1 shows the IRIS database details [20] and Figure 3 has samples of the used data thermal images.

Table 1. IRIS Database Information

| No. of Population | Status | | Resolution | No. of Images | |
|---|---|---|---|---|---|
| 30 | Expressions | 3 | 320*240 | Thermal | ~1529 |
| | Illumination | 6 | | | |
| | Poses | 11 | | Visible | ~1529 |


Figure 3. Samples of used data images

**4.2. Results and Discussion**

The experimental results have two main approaches. The first, applying KNN and SVM with multiple features directly over the selected data. Second approach, applying KNN and SVM with multiple features based on DCT over the tested thermal images.

Experimental results of the first approach indicates that using local standard deviation as an extractor under KNN or SVM has the highest recognition rate 63.33% and 73.33% respectively. Tables 2 and 3 show the detailed confusion matrix for both previous cases and the values of True Positive (TP) and False Negative (FN) rates for each expression Table 4 has the recognition rates for multiple features (LE, LSD and PCA) which are used directly with the KNN and SVM classifiers.

Table 2. Confution Matrix of KNN Based LSD

| | Surprise | Happy | Angry | TPR | FNR |
|---|---|---|---|---|---|
| Surprise | 6 | 3 | 0 | 60% | 40% |
| Happy | 4 | 7 | 4 | 70% | 30% |
| Angry | 0 | 0 | 6 | 60% | 40% |

Table 3. Confution Matrix of SVM Based LSD

| | Surprise | Happy | Angry | TPR | FNR |
|---|---|---|---|---|---|
| Surprise | 6 | 3 | 0 | 60% | 40% |
| Happy | 4 | 7 | 4 | 70% | 30% |
| Angry | 0 | 0 | 6 | 60% | 40% |

The Second approach of the results that uses KNN and SVM with multiple features based on DCT shows that: local standard deviation has higher recognition rate 83.33% than other features (LE and PCA) under the SVM classifier. While Local Entropy has the highest recognition rate with 90% under the KNN classifier based on the DCT filter. Table 5 shows the confusion matrix of KNN based on LE and DCT. Table 6 shows the confusion matrix of SVM based on LSD and DCT with the TP and FN rates. Tables 7 and 8 results illustrate the detailed accuracy by class (Surprise, Happy and Angry) of KNN Based on DCT and the detailed accuracy by class of SVM Based on DCT. Table 9 has the recognition rates for multiple features (LE, LSD and PCA) that used under the KNN and SVM classifiers based on the DCT technique which show that KNN has recognition rate 90% with LE feature and 80% with LSD feature while, SVM 73.33% recognition rate with the LE and 83.33% with LSD feature.

Table 4. Classifiers and Features Performance Comparison without DCT

| Classifier | Feature | Accuracy (%) |
|---|---|---|
| | PCA | 60 |
| KNN | LSD | 63.33 |
| | LE | 33.33 |
| | PCA | 43.33 |
| SVM | LSD | 73.33 |
| | LE | 33.33 |

Table 5. Confution Matrix of KNN Based LE+DCT

| | Surprise | Happy | Angry | TPR | FNR |
|---|---|---|---|---|---|
| Surprise | 9 | 1 | 0 | 90% | 10% |
| Happy | 0 | 8 | 0 | 80% | 20% |
| Angry | 1 | 1 | 10 | 100% | 0% |

Table 6. Confution Matrix of SVM Based LSD+DCT

| | Surprise | Happy | Angry | TPR | FNR |
|---|---|---|---|---|---|
| Surprise | 9 | 0 | 0 | 90% | 10% |
| Happy | 0 | 6 | 0 | 60% | 40% |
| Angry | 1 | 4 | 10 | 100% | 0% |

Table 7. Detailed Accuracy by Class of KNN Based DCT

| Classifier | Class | Feature+DCT | Accuracy (%) |
|---|---|---|---|
| | | LSD | 100 |
| | Surprise | LE | 90 |
| | | PCA | 70 |
| | | LSD | 40 |
| KNN | Happy | LE | 80 |
| | | PCA | 50 |
| | | LSD | 100 |
| | Angry | LE | 100 |
| | | PCA | 60 |

Table 8. Detailed Accuracy by Class of SVM Based DCT

| Classifier | Class | Feature+DCT | Accuracy (%) |
|---|---|---|---|
| | | LSD | 90 |
| | Surprise | LE | 70 |
| | | PCA | 90 |
| | | LSD | 60 |
| KNN | Happy | LE | 70 |
| | | PCA | 10 |
| | | LSD | 100 |
| | Angry | LE | 80 |
| | | PCA | 10 |

Table 9. Classifiers and Features Performance Comparison Based DCT

| Classifier | Feature | Accuracy (%) |
|---|---|---|
| | PCA | 60 |
| KNN | LSD | 80 |
| | LE | 90 |
| | PCA | 36.33 |
| SVM | LSD | 83.33 |
| | LE | 73.33 |

Overall results implicate that the highest expression recognition rate was made by the Local Entropy feature under the K-Nearest Neighbor classifier based on DCT filter with 90%. Figure 4 shows visualization of the classification results made using NodeXL tool. This work uses mostly the learner classifiers and features of MATLAB R2014a.

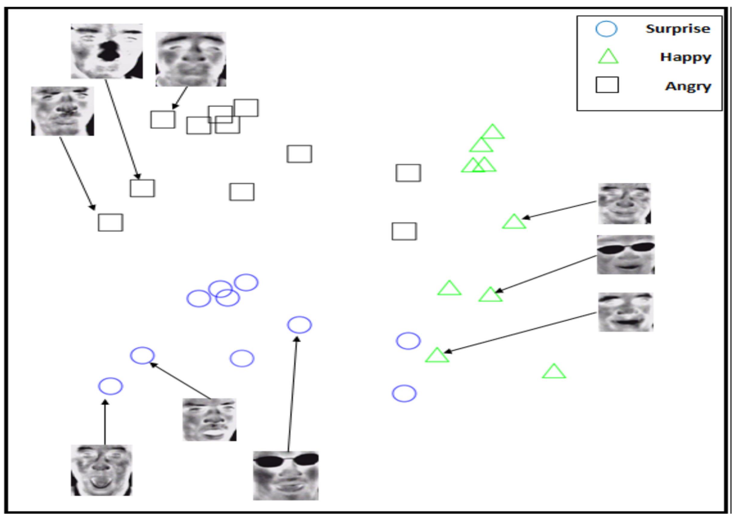


Figure 4. Classification result visualization of using KNN+LE based DCT

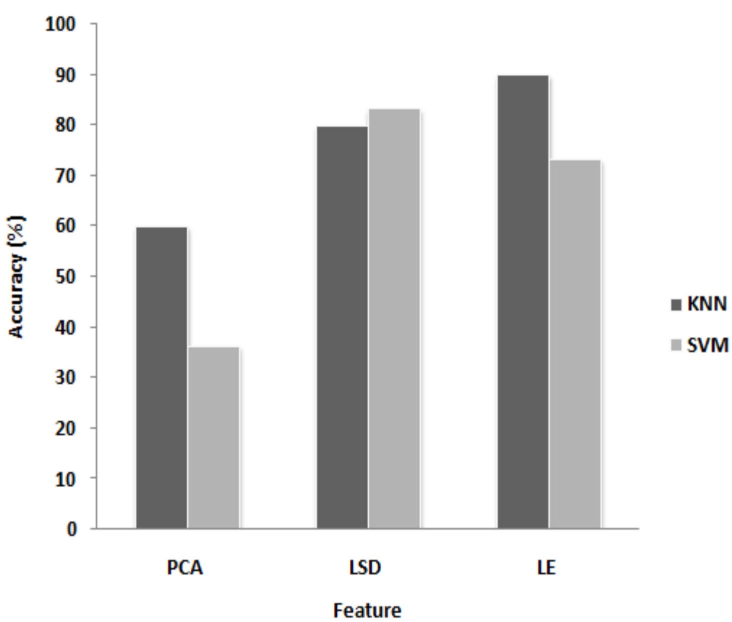


Figure 5. Accuracy rate for feature extractors using classification methods based DCT

## 5. CONCLUSION

This paper holds two main approaches of conducted results, one based on applying DCT filter over the selected dataset and other without using it in order to present more efficient model for expression recognition in thermal images. The first approach uses K-Nearest Neighbor and Support Victor Machine classifiers with multiple features extraction (LE, LSD and PCA) without applying DCT and experimental results show that the Local Standard Deviation gives high accuracies with both KNN and SVM but higher with SVM with 73.33% recognition rate.

The second approach applies KNN and SVM with multiple features extraction based on applying DCT filter. Experimental results show that generally applying the DCT improves the recognition rates over most used features extraction (LE and LSD) as shown in table IX. But the most efficient model with the highest accuracy 90% uses the Local Entropy as feature extractor and KNN as classifier based on the DCT as appears in Figure 5. Experimental results on IRIS database demonstrate that the proposed model gives feasible recognition rates although the occlusion by glasses and pose variation of the expressions.

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